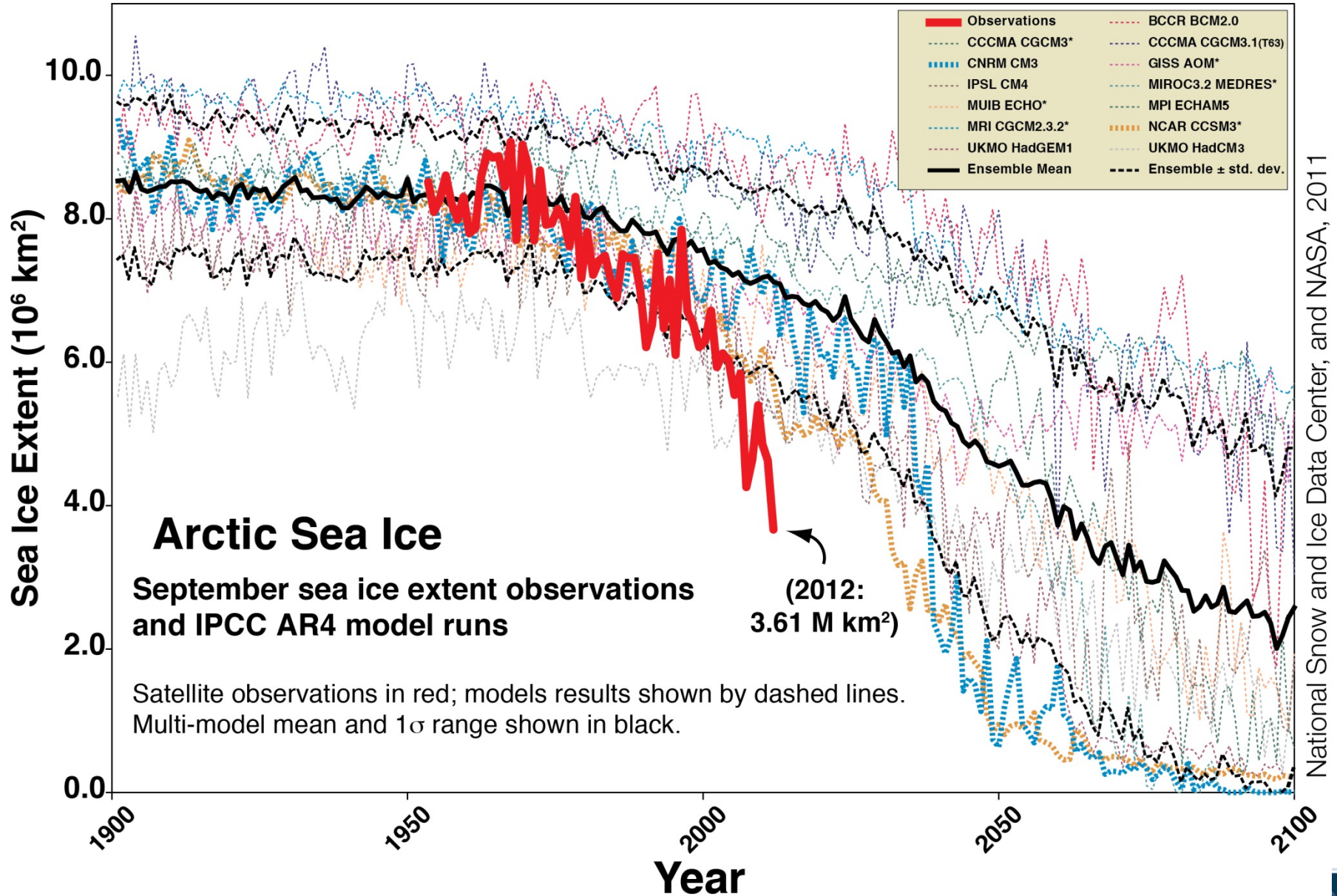




Evolution of Arctic Sea Ice in CMIP5, CMIP5 and Observations

Julienne Stroeve and Andrew Barrett

Introduction

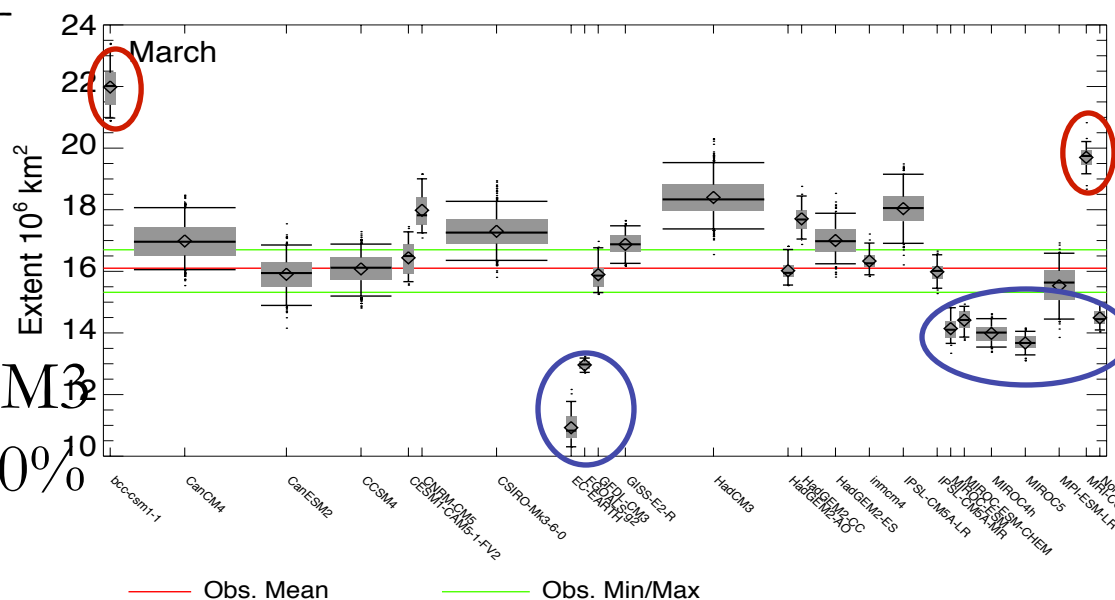
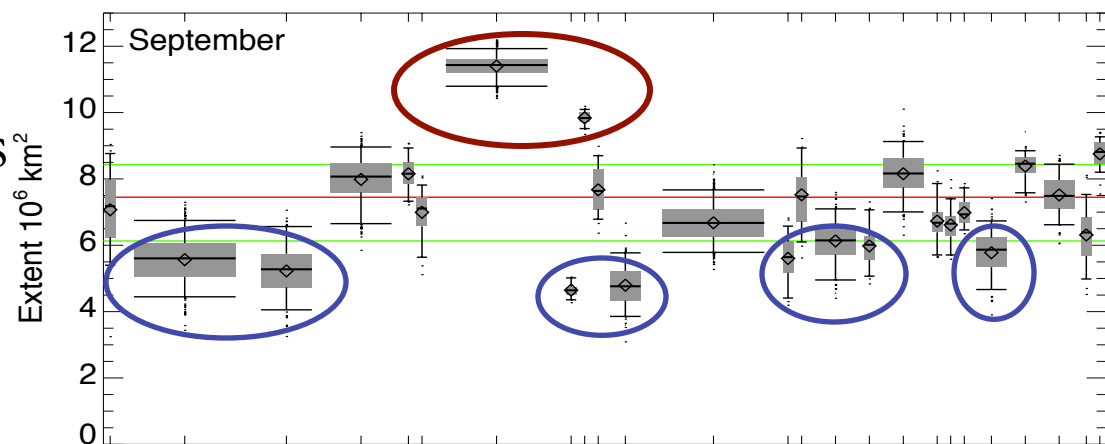


Metrics Evaluated

- 105 ensembles for historical, 77 for RCP4.5
- 1953-1995 climatology;
- 1953-2011 and 1979-2011 seasonal cycle;
- September and March extent time-series and trends;
- September and March volume;
- Spatial pattern of sea ice thickness during ICESat (spring 2004-2008).
 - While the observational record is short, this assessment looks at the ability of the models to produce the main features of the thickness distribution, first observed in submarine ice draft in the 1950s.

Assessment of 1953-1995 Climatology

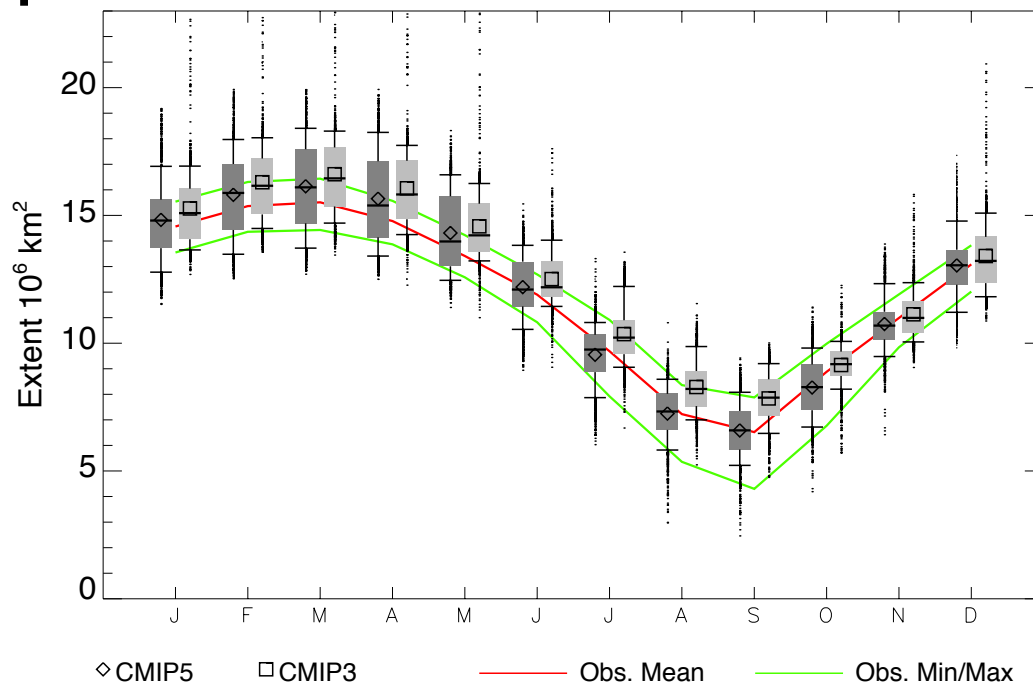
CMIP5 1953 to 1995 Extent



- Box and whisker plots – width of each box represents # of ensembles
- For September, most models tend to underestimate ice extent.
 - CanESM, GISS E2-R/E2-H, HadGEM2-ES, INMCM4 and MIROC4h fall below 20% of 1953-1995 mean
- During winter, MRI-CGCM3 and bcc-csm1 fall above 20% of 1953-1995 mean

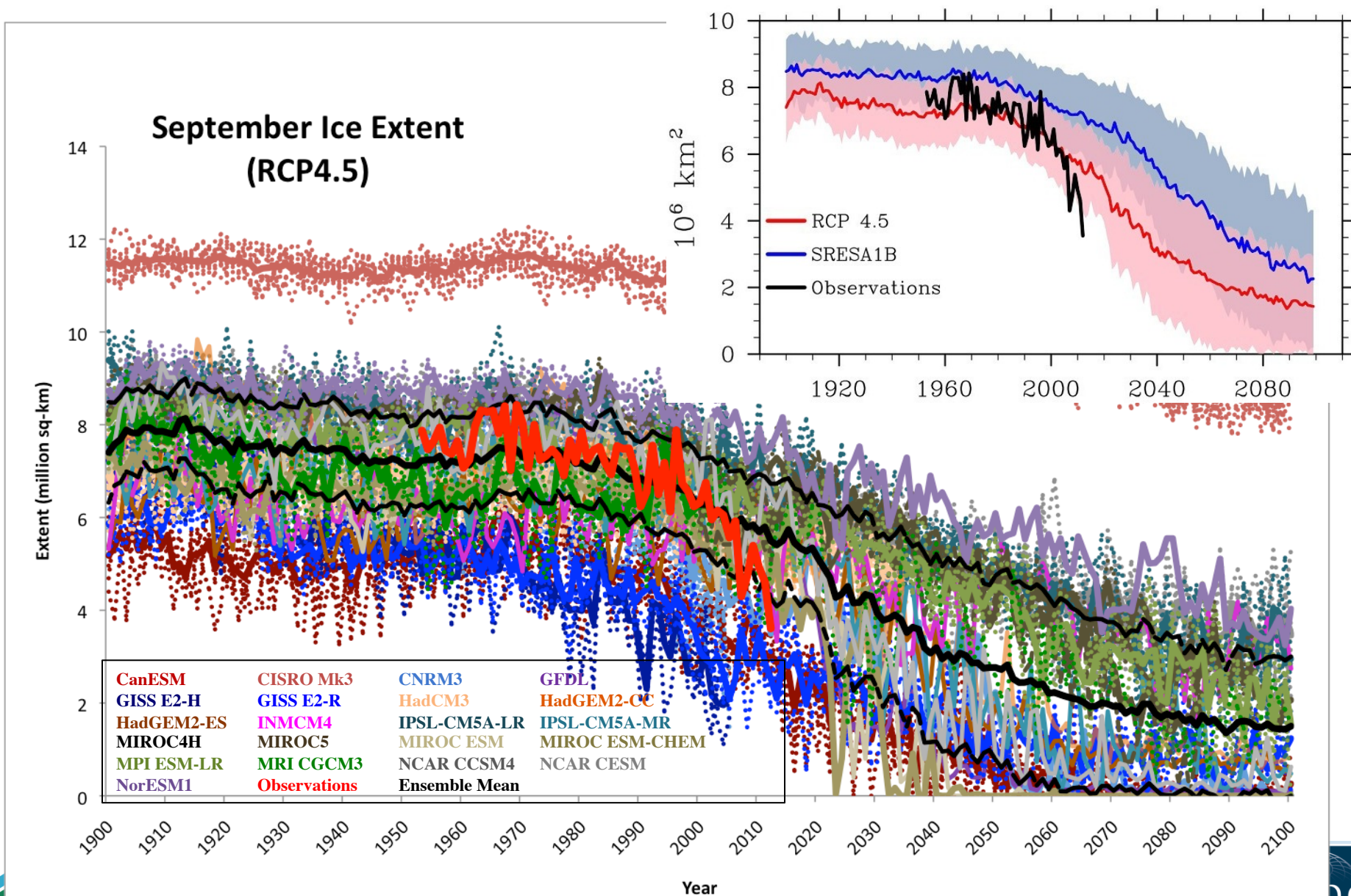
Seasonal Cycle – Multi-Model Ensemble Mean

Comparison of CMIP3 and CMIP5 Seasonal Cycle



- CMIP5 multi-model ensemble mean excludes GISS-E2-R, CSIRO MK3
- CMIP3 multi-model ensemble mean excludes CSIRO MK3, GFDL-CM2-1, GISS-E-R, INGV ECHAM, INMCM3, MIROC-3.2-hires

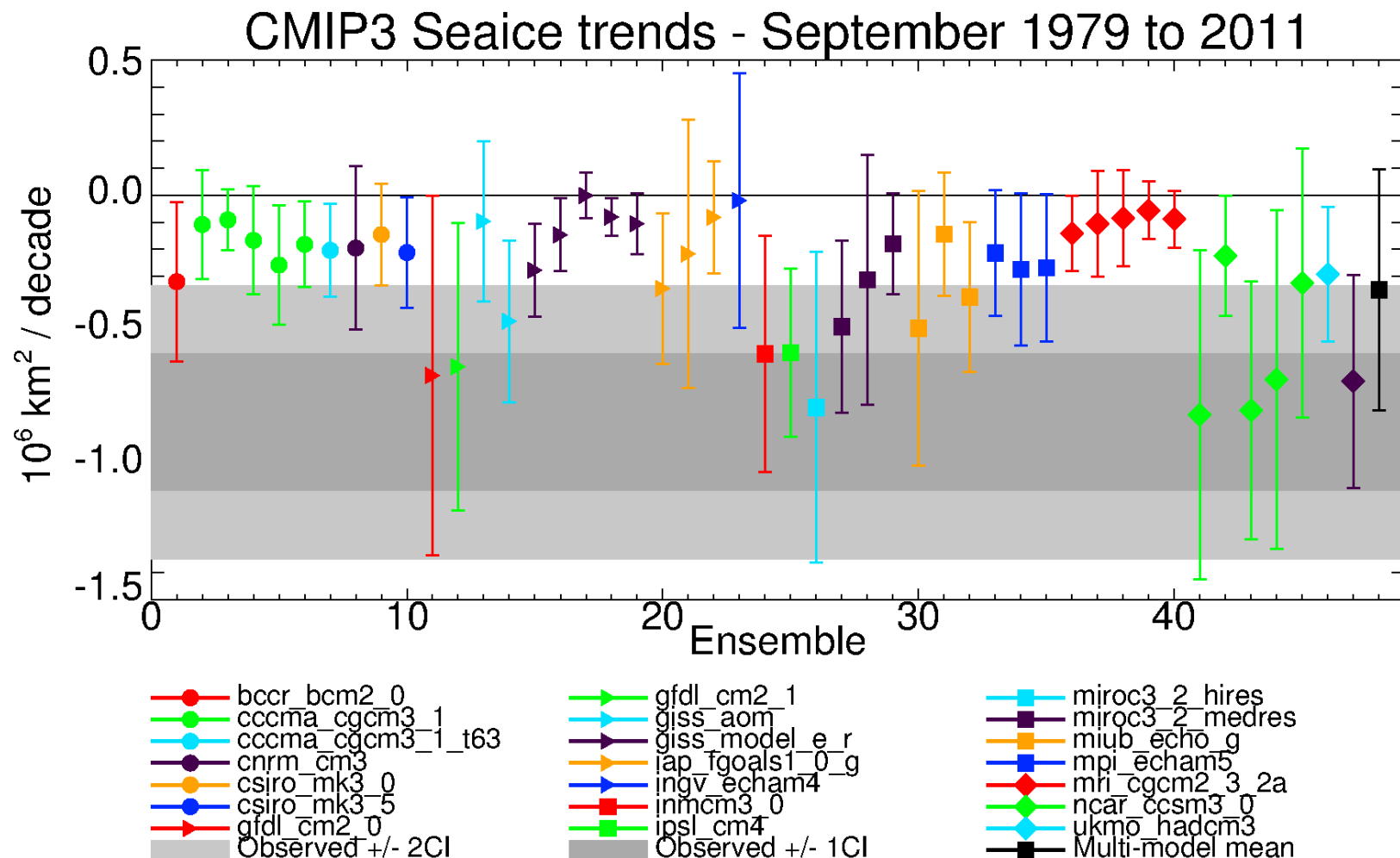
Evolution of September ice extent



September trends

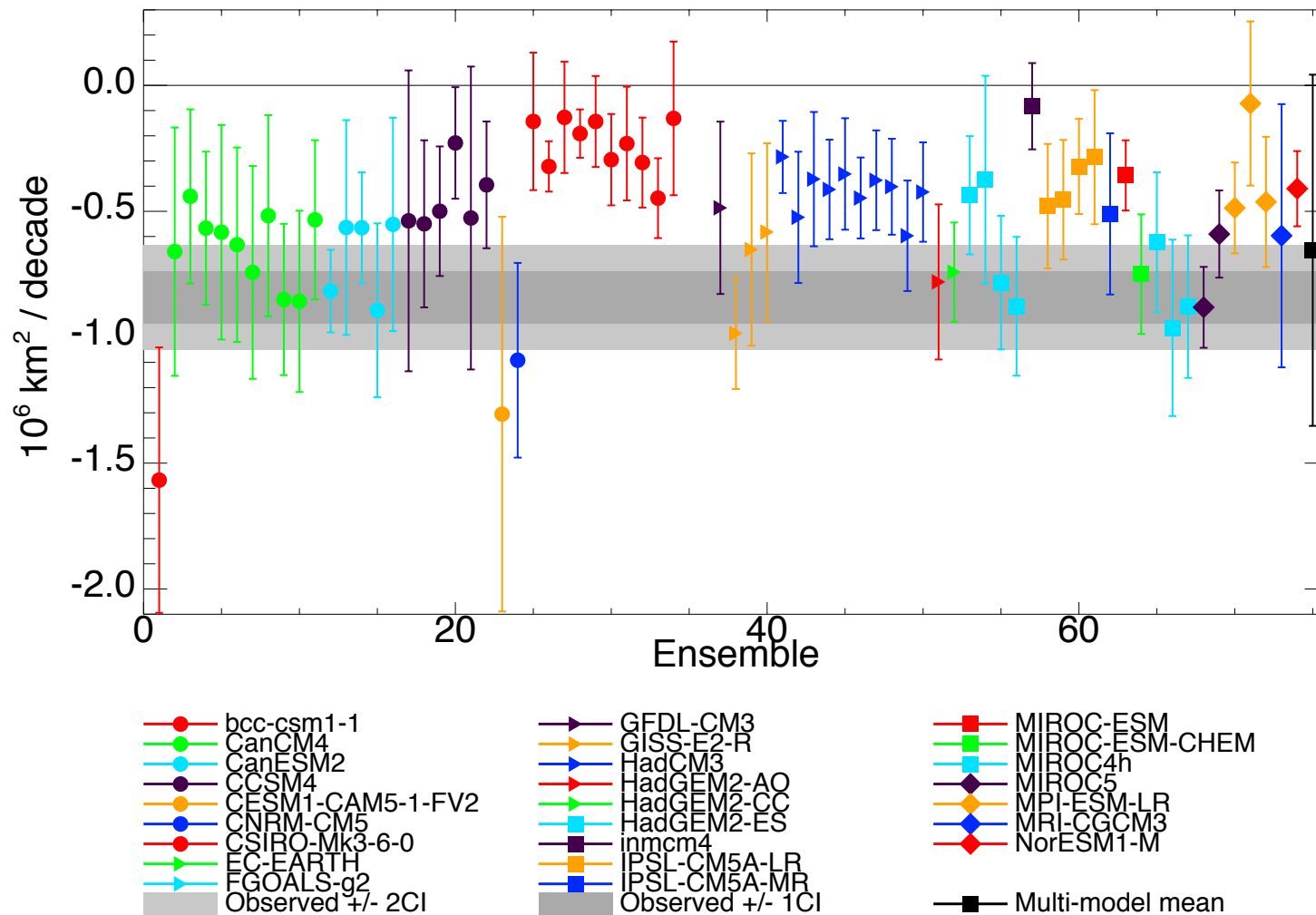
- While the CMIP5 models better capture the observed September extent it's important to assess how well they capture the rate of decline compared to CMIP3.
- Following *Santer et al.* [2008] we compute trends and standard deviation after accounting for lag-1 autocorrelation.

September trends: CMIP3



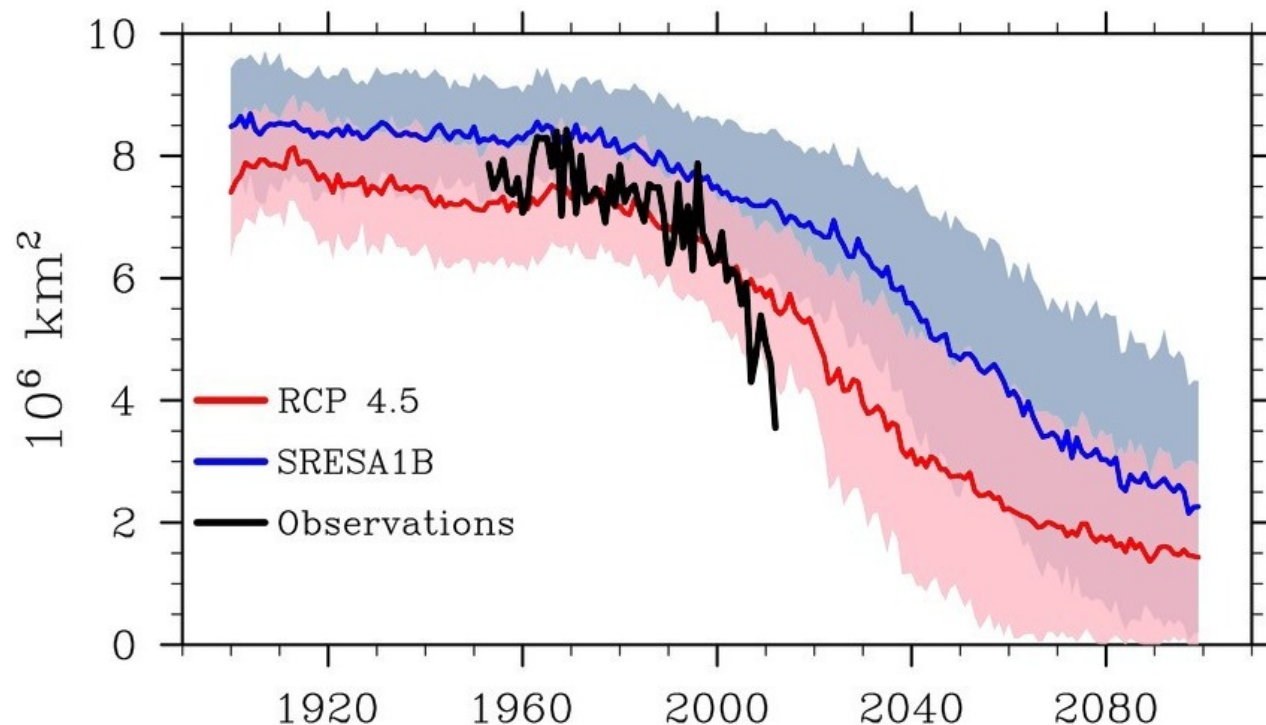
September trends: CMIP5

CMIP5 Seaice Extent Trends



Comparison of CMIP3 and CMIP5

September Ice Extent



1953-2011

Observed = $-6.8 \pm 0.7\%/dec$

RCP4.5 = $-4.1 \pm 0.29\%/dec$

SRESA1B = $-2.8 \pm 0.17\%/dec$

1979-2011

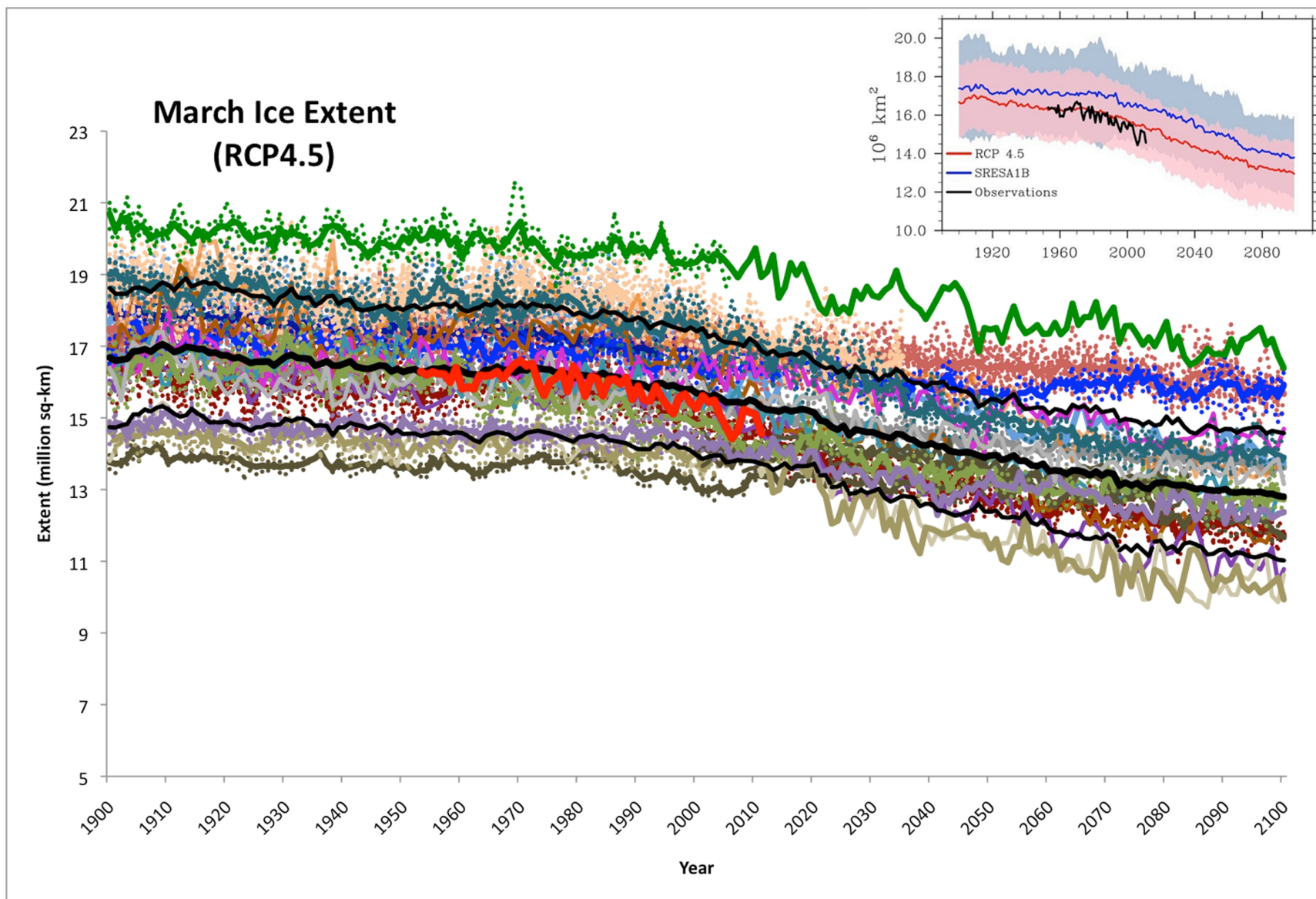
Observed = $-14.03 \pm 1.55\%/dec$

RCP4.5 = $-8.1 \pm 0.30\%/dec$

SRESA1B = $-4.5 \pm 0.19\%/dec$

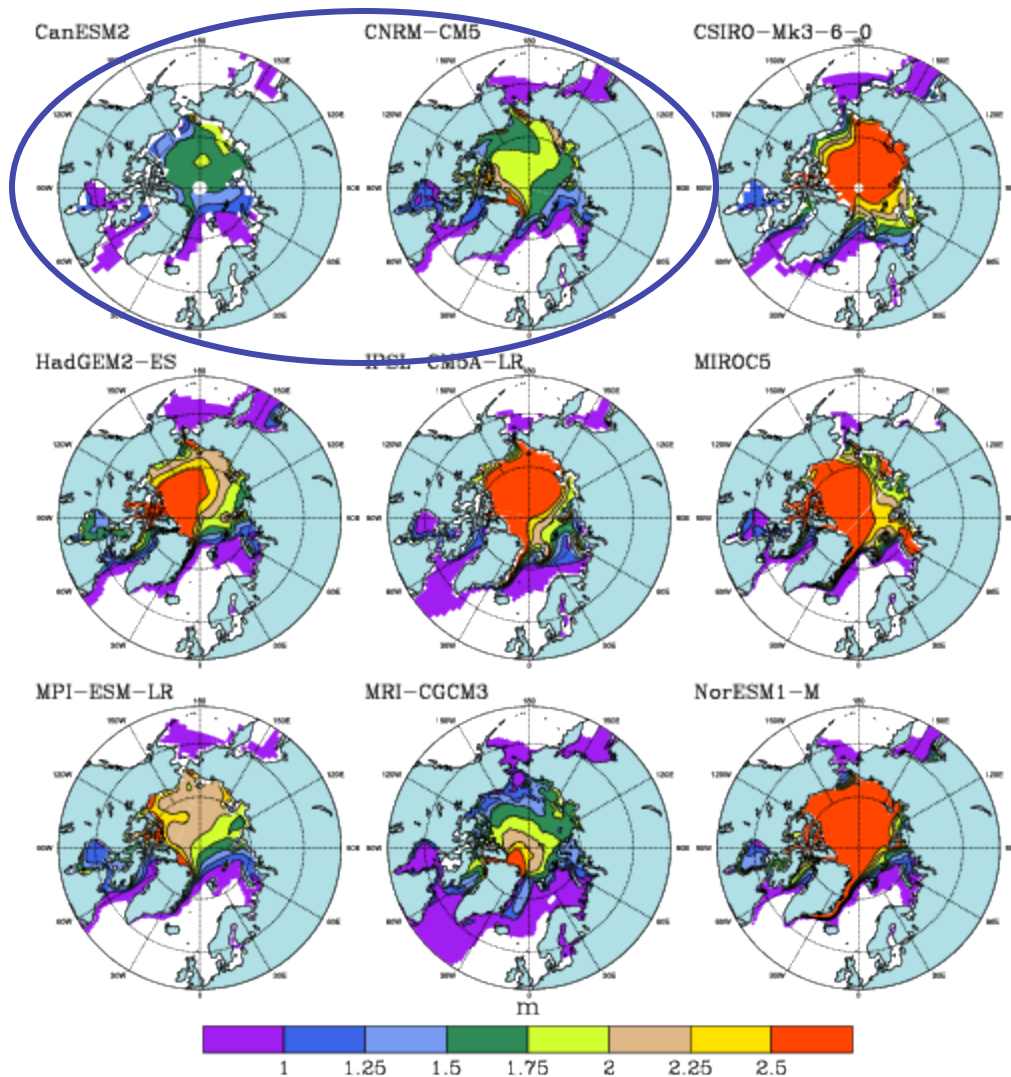
From 1953-2011 RCP4.5 multi-model mean suggests 59% of the observed trend is externally forced. From 1979-2011 it is 54%.

March ice extent

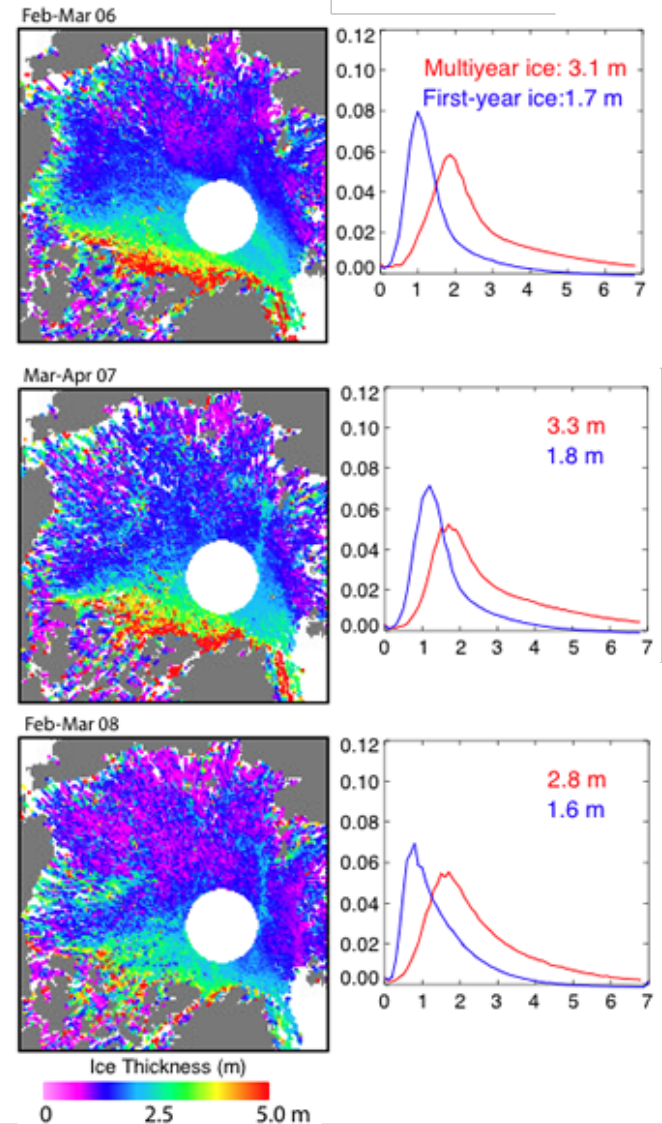


Ice thickness (March)

CanESM 1953-1995 Sep SIE=5.23 10^6 km^2



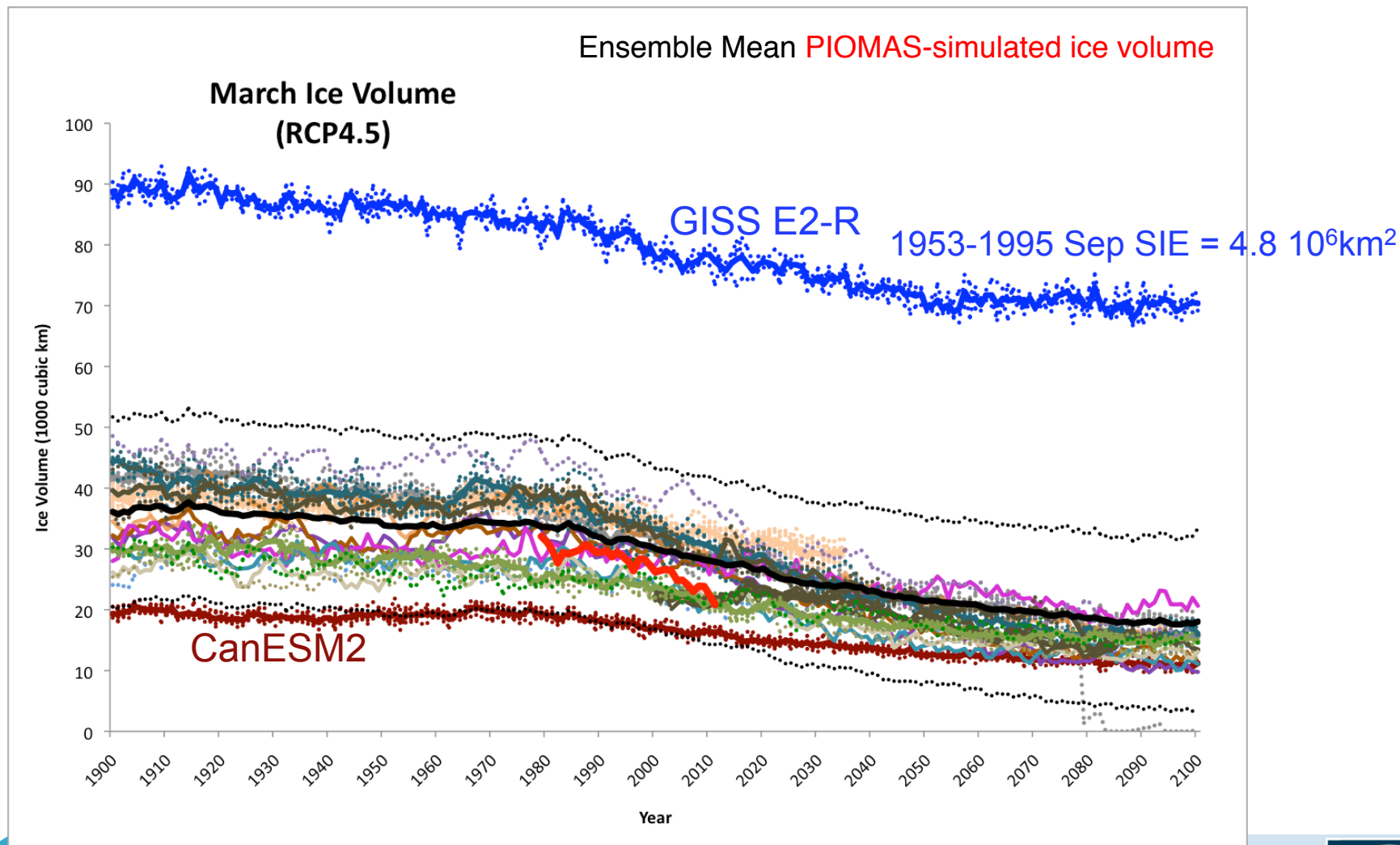
ICESat Thickness Estimates



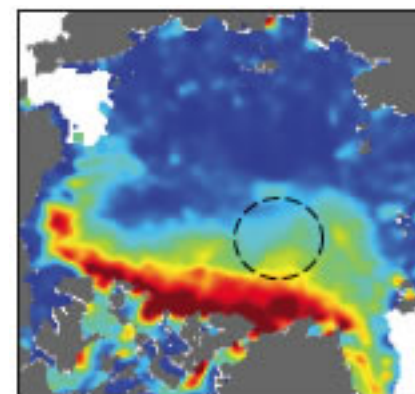
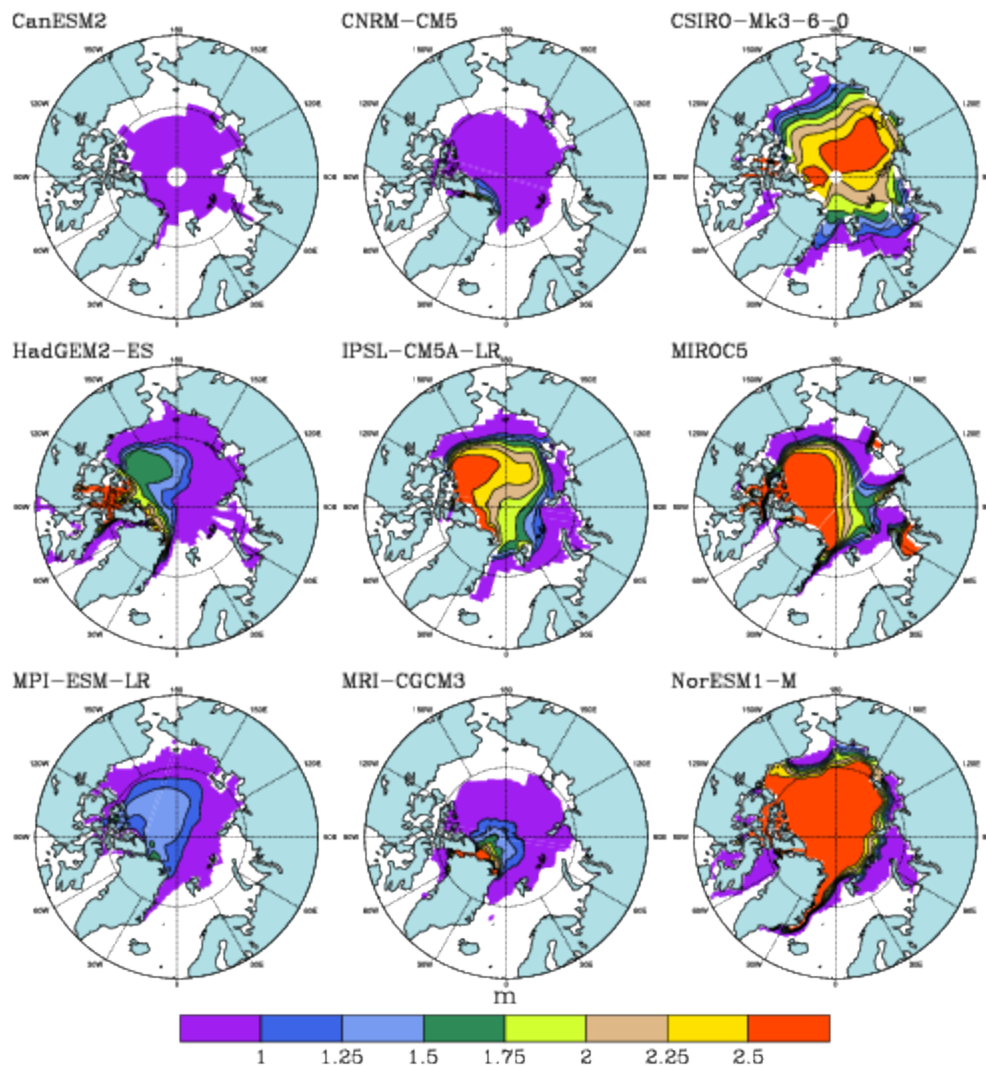
National Snow and Ice Data Center courtesy Ronald Kwok, NASA Jet Propulsion Laboratory

Ice volume (March)

Winter Maximum (March)



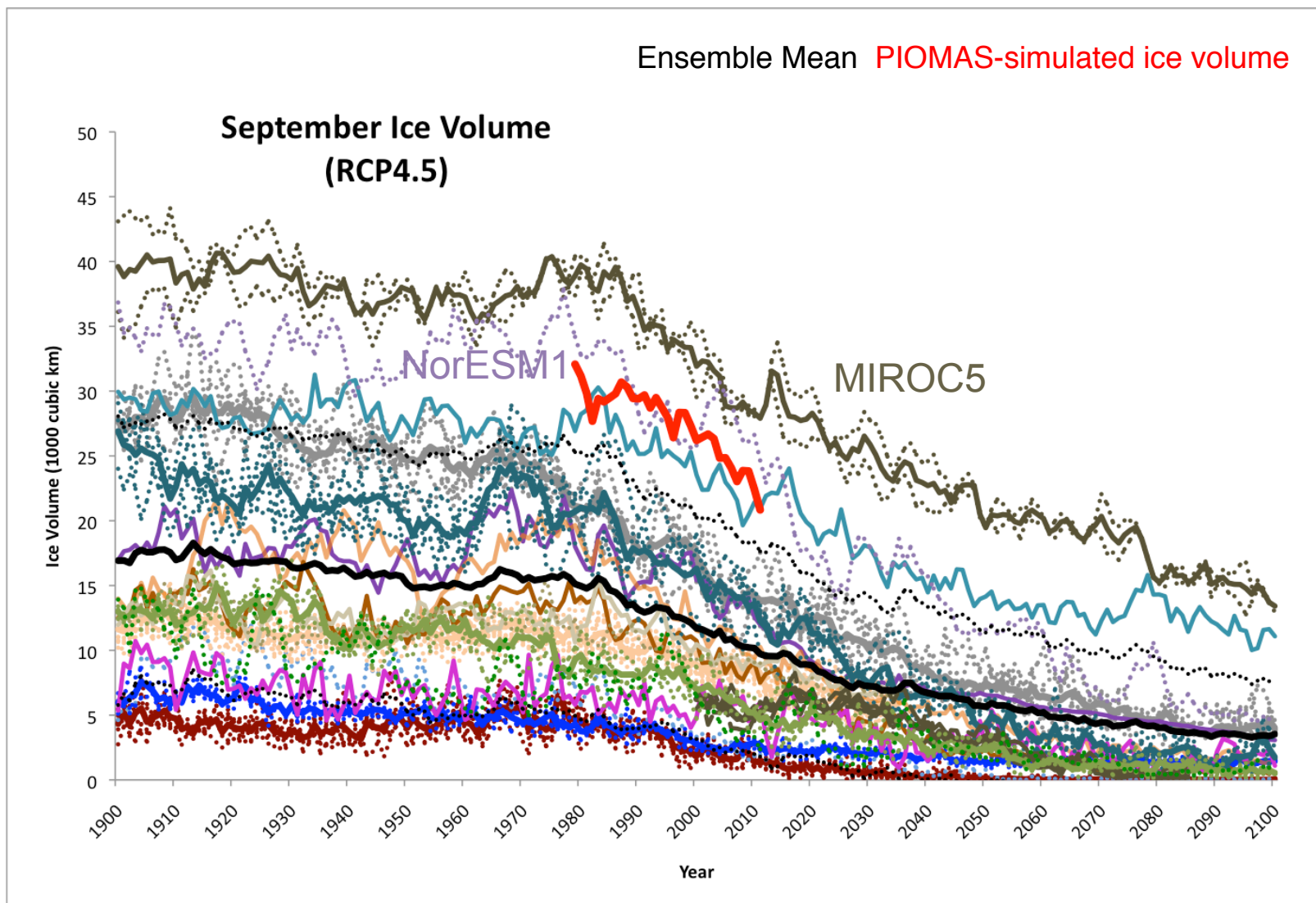
Ice thickness (September)



ICESat ON05
from R. Kwok

Ice Volume (September)

Summer Minimum (September)



Summary

- In general, CMIP5 models better capture the observed decline in Arctic sea ice than CMIP3.
 - However, several models GISS, MIROC4, HadGEM-ES, INMCM4 and CAN ESM fall below 20% of 1953-1995 climatological mean for September.
- In general, the models exhibit a stronger seasonal cycle in both extent and volume than CMIP3 or observed.
- Large inter-model scatter remains in both ice extent and ice volume, particularly in ice volume estimates .
- The spatial variability of thickness, a large-scale slowly varying climatic feature of the ice cover remains not well produced by the majority of the models.